

Standard Operating Procedure #3: Using the Global Positioning System (GPS)

Version 1.2 (2021)

In Water Quality Monitoring Protocol for Inland Lakes: Great Lakes Inventory and Monitoring Network

Prepared by

David VanderMeulen* and Mark Hart

National Park Service

Great Lakes Inventory and Monitoring Network

2800 Lake Shore Drive East

Ashland, Wisconsin 54806

** Contact author: david_vandermeulen@nps.gov*

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Revision History Log

The following table lists all edits and amendments to this document since the original publication date. Information entered in the log must be complete and concise. Users of this standard operating procedure will promptly notify the project manager and/or the Great Lakes Network (GLKN) data manager about recommended and required changes. The project manager must review and incorporate all changes, complete the revision history log, and change the date and version number on the title page and in the header of the document file. For complete instructions, please refer to Revising the Protocol, SOP #13.

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
1.0	5/01/2015	David VanderMeulen, GLKN	Updated the NPS contact author, removed references to specific versions of software, fixed a handful of grammatical errors throughout.	To clarify and update SOP based on changes that have occurred since Version 1.0 was published in 2008	1.1
1.1	3/2021	Alexander Egan, Aquatic Ecologist, GLKN	Minor grammatical changes; modify text to avoid outdated technologies or include new GPS options.	To clarify and update SOP based on changes that have occurred since Version 1.1 was published in 2015	1.2
Add rows as needed for each change or set of changes tied to an updated version number					

Acknowledgements

Major portions of this SOP have been adopted from the GLKN GPS Field Data Collection Guide. The guide was originally published as Appendix K to the Great Lakes Inventory and Monitoring Data Management Plan (Hart and Gafvert 2005). Appendix A of this SOP was also adopted from that document and contains a summary discussion of the general types of GPS units available, as well as definitions of terms commonly associated with use of GPS units.

3.0 Introduction

This Standard Operating Procedure (SOP) provides guidance on some of the more common operations associated with global positioning system (GPS) units. Although most GPS units are capable of multiple functions, only those operations relevant to the protocol established to monitor water quality on inland lakes (Elias et al. 2007) are discussed.

Water quality monitoring staff utilize both mapping and recreational-grade GPS units. The Trimble Geo series is an example of a mapping-grade GPS unit, while the Garmin GPSMAP series is an example of a recreational-grade unit. Mapping-grade units record data with location accuracy of less than one meter. Recreational-grade units generally are not as accurate, but current models have a spatial accuracy of less than 5 meters. Mapping-grade units have greater ability to capture spatially referenced metadata (i.e., attributes) than recreational-grade GPS. A detailed discussion of these types of GPS can be found in Appendix A.

Software pertinent to the use of these GPS units includes:

- Trimble TerraSync mapping-grade GPS unit software
- Trimble GPS Pathfinder Office desktop GPS processing software
- ESRI ArcGIS desktop GIS software or ArcGIS Online
- Minnesota Department of Natural Resources DNRGPS Application – desktop application to transfer data between recreational-grade GPS units and GIS software
- NPSTORET and Aquarius software, NPS database for water quality data (refer to SOP #8, Data Entry and Management)
- Smart phones and tablets also offer reasonably accurate GPS apps, which may be considered as a backup to dedicated GPS units

Due to the rapid development of commercial software and hardware capabilities, it is likely that other GPS units or software will be utilized in the future. Therefore, this SOP is meant to act as a working document that is updated periodically as new hardware and software becomes available. Although nomenclature may differ depending on what hard-software is utilized, this document should provide sufficient guidance on the general process of data collection using GPS tools until the SOP is revised. It is strongly recommended that water quality monitoring staff obtain unit-specific GPS training prior to deploying in the field. The training should include hands-on use and should be designed to test all appropriate functions and operations prior to going out into the field.

Additionally, this SOP is not intended to be exhaustive or simply a regurgitation of operating manuals, but a document that might be carried into the field or periodically reviewed by field technicians and project leaders. Although some of the information in this SOP is specific to the water quality monitoring effort by GLKN, much of the text contained herein is applicable to other data collection efforts by GLKN staff. The objective of this document is to summarize GPS use guidelines applicable to the water quality monitoring efforts for inland lakes at GLKN parks.

3.1 Role of GPS in Water Quality Monitoring on Inland Lakes

GPS units are primarily used in the following ways to support water quality monitoring on inland lakes:

1. Permanent markers on the shore are installed in order to measure water level relative to the marker. GPS units are used to record the location of each marker and the bearing and distance between the marker and a known landmark (e.g., fire-ring at a campsite). A detailed discussion of how reference markers are installed and water level is measured is found in SOP #4, Measuring Water Level. It is recommended that a mapping-grade GPS unit be used to obtain a higher precision location during installation of reference markers. These coordinates, along with detailed descriptions, should be used to relocate the marker.
2. For water quality monitoring on inland lakes, navigating to and sampling at the position locations of monitoring stations is accomplished through a combination of:
 - Using GPS units to navigate to previously established GPS point locations
 - Using hardcopy topographic maps and written notes with site descriptions
 - Using a depth sounder to verify site is at the deepest location
 - Comparing digital photos taken during site establishment with observer ocular estimates
 - Field experience of NPS staff conducting the monitoring
3. Accurate station location descriptions must be recorded and carefully followed by sampling personnel on subsequent field visits for water quality monitoring. Therefore, once on station, GPS equipment is used to obtain the station's coordinates, which allows the user to spatially reference water quality monitoring data to specific geo-referenced locations for each sampling event.

Additional uses of the GPS units may develop over time if protocols change or other needs are identified. For example, the Great Lakes Network currently promotes the use of electronic data logging equipment to enhance data quality and simplify data management. Many water quality parameters (e.g., pH) are now primarily recorded with electronic data logging equipment, while others (Secchi disk depth, names of observers, etc.) are logged on hardcopy only. Therefore, GPS units capable of logging more information other than just waypoints (e.g., Trimble GeoXT) could be programmed to allow for electronic recording of these parameters. The next two sections of this SOP will outline some of the more common and pertinent functions associated with mapping and recreational-grade GPS units, which are the types of units currently used by GLKN staff for water quality monitoring.

3.2 Using Mapping-Grade GPS Units

All mapping-grade GPS users should become familiar with GLKN GPS collection procedures and relevant manufacturer's user guides and operating manuals before GPS operation. Hardware and software upgrades and NPS-DOI approved products will change over time. Prior to using mapping-grade GPS units, consult GLKN data managers for appropriate tools for the desired outcomes.

Mapping-grade GPS units provide the user with a variety of tools for field data collection. GLKN encourages the use of these units for most projects. These units can be used to acquire spatial data related to points, lines, and polygons along with associated, user defined, tabular attributes. Careful forethought and advanced planning are required to take advantage of these capabilities long before data collection begins.

3.2.1 Data Dictionaries

TerraSync software on mapping-grade GPS units is capable of using data dictionaries. Data dictionaries define the structure and rules to store attribute information about the feature being mapped and are customized for each project. GLKN data management personnel should be directly involved in the creation of data dictionaries. Basic steps include:

1. Identify the features to be mapped. These features are real world physical locations of objects (e.g., a water quality monitoring station) that are categorized as point, line, or polygon features.
2. Identify the attributes to be collected for each feature while in the field and create a data dictionary. Part of this process is assigning a unique identifier to each feature. (For example, if a survey plot is mapped as both a point and a polygon, one feature should be named `plotname_poly` and the other `plotname_pt`).
3. Implement and test the data dictionary. Field staff should conduct a complete trial run for newly created data dictionaries before beginning field work. Corrections and refinements are inevitable after such a trial.

Because most of the data for water quality monitoring on inland lakes are recorded by electronic sampling equipment, there has not been much incentive to utilize data dictionaries. However, as discussed earlier, it is possible that the few parameters not currently logged electronically could be incorporated into a data dictionary and recorded. As stated above, it is highly recommended that GLKN data management personnel be involved in this process, and that once created, the data dictionary only be altered with permission from data management personnel. This will reduce the potential for confusion and mistakes when data are processed at the end of the field season.

3.2.2 GPS Settings

Positional accuracy of GPS data can be affected by several factors that can be monitored and recorded with mapping-grade GPS units. Table 1 lists these factors, their definitions, and the standard settings for GLKN field work. All spatial data collected shall be analyzed for spatial accuracy and shall meet or exceed the National Map Accuracy Standards (Table 1 in Appendix A, and

<https://www.usgs.gov/core-science-systems/ngp/ss/product-standards>). Table 2 indicates the coordinate system settings for data collection in GLKN parks.

Table 1. GPS receiver settings, definitions, and standards for use at GLKN parks.

Setting Name	Definition	GLKN Setting Standard
Almanac	File containing estimated position of satellites, time corrections, and atmospheric delay parameters	Acquired automatically by GPS unit or from online sources within 10 days prior to GPS field work
Altitude reference	Ellipsoid model	Height above Ellipsoid (HAE) (preferred) or Mean Sea Level: if MSL is used, indicate Geoid Model
Antenna height	GPS antenna height above the ground	Variable, usually 1.0 meters for handheld and 1.5 m for backpack
Datum	Geodetic model designed to fit a point on the earth's surface to an ellipsoid	NAD 83 (CONUS) [preferred] WGS 84 [GPS default, as fallback] NAD 83 (CONUS) (CORS 96) [for H-Star use with GeoXH Trimble GPS Unit]
Elevation mask	The minimum angle above the horizon at which a GPS receiver will track a satellite	15 degrees
Feature types	Geometry of spatial data	GIS native formats; point, line and polygon are preferred
Logging interval	Time interval between the recording of individual GPS fixes	Points: 1 second Lines and Polygons: 5 seconds, but 1 second in some circumstances
Minimum fixes for point positions	Number of GPS fixes that are used to calculate a single position for a point feature	50 fixes (120 points in the case of GeoXH)
Mode	2 dimensional for horizontal positions and 3 dimension with an elevation position	3-dimensional (4 satellite minimum)
PDOP mask	Positional Dilution of Precision, a GPS quality estimate based on satellite geometry	6.0 or less
Real-time settings	GPS unit may be capable of performing differential correction of data during collection	Select Integrated WAAS (unless using H-star, e.g., XH unit); setting will be 'auto' or 'on'
Satellite vehicles	Number of satellites used for position fixes	4 minimum
SNR mask	Signal-to-Noise ratio is a measure of the satellite signal relative to background noise	4.0 minimum, 6.0 or greater preferred
Unit of measure	Linear unit of measure	Meter (metric)

GPS signals are received in the WGS84 datum. Processing and transformation of the positional information to other datums can take place internally in the GPS unit or in software, either the GPS data processing software (see below) or in GIS software. GPS data that will receive no post-processing differential correction, unlikely with a mapping grade receiver, can be collected in native WGS84 or NAD83 (CONUS), and ensuring that the datum used is recorded in the metadata. More likely with a mapping grade receiver, the GPS data will be differentially corrected after collection using data from one or more reference base stations. Data on the GPS unit should be collected in the same datum as the data are output from the reference base stations. The majority of public base stations in the US are part of the National Geodetic Survey's Continuously Operating Reference Station (CORS) network; and output information in the NAD83 (CONUS) CORS datum. Setting the GPS unit to record data in NAD83 (CONUS) CORS datum will result in the most accurate spatial information when differentially corrected against a CORS base station. A very high precision mapping grade unit may use H-Star technology, which requires post collection differential correction; using the NAD83 (CONUS) CORS datum and no real-time correction (WAAS) on the GPS unit, and correcting against a group of CORS base stations is necessary to realize the maximum accuracy from an H-Star receiver.

Table 2. Coordinate system settings for Great Lakes Network parks. Bold font indicates parks where water quality monitoring on inland lakes will take place.

Park	UTM Zone	Datum
APIS	15	NAD 1983 (Conus)
GRPO	16	NAD 1983 (Conus)
INDU	16	NAD 1983 (Conus)
ISRO	16	NAD 1983 (Conus)
MISS	15	NAD 1983 (Conus)
PIRO	16	NAD 1983 (Conus)
SACN	15	NAD 1983 (Conus)
SLBE	16	NAD 1983 (Conus)
VOYA	15	NAD 1983 (Conus)

Before beginning data collection, the GLKN data management staff or the GPS user should complete some mission planning tasks. If high accuracy fixes are desired and there is some flexibility in scheduling of a field data collection mission, the user should complete a satellite survey to determine the best timing of the mission, usually when the most satellites are visible and in the best geometry. Software, such as Trimble's Quick Plan (also included in Pathfinder Office) can be used to look for time windows that should offer the lowest PDOP readings, and thus the highest positional accuracy.

If a project requires navigation to preset locations or waypoints, this information must be pre-loaded onto the GPS hardware before starting a field data collection mission, unless the locations have been previously stored on the GPS. Having printed copies of bathymetric maps with sampling sites marked is a good backup and can maximize field time and efficiency. Some of the sampling stations on inland lakes are located relative to unique shoreline features (e.g., rock outcrop, island, bay),

which are annotated on topographic maps. Detailed descriptions and photographs of the shoreline are also used to navigate to designated sampling sites.

Many mapping-grade GPS units have the capability of storing and displaying background maps or GIS layers, which can be helpful when navigating in the field. For example, topographic maps of Isle Royale National Park can be used with GPS units to find lakes that are off-trail. The GLKN data management staff can support preparation of these background layers and, if necessary, assist in loading them onto the GPS hardware.

GPS units create files to store data during a field session using a prefix and date-time stamp as file names. For example:

RMMDDHHx

R – Unit Prefix

MM – Month

DD – Day

HH – Hour

X – a, b, c, etc., the order files are created within an hour

If multiple GPS units are used for a project, a unique prefix (letter) should be assigned to each unit, which will ensure that downloaded files for each unit contain a unique identifier within the filename. For example, with three GPS units, the unique letters for the units could be N, G, and A. Those letters would serve as a prefix for the file n (e.g., N102715A, G102715A, and A102715A would indicate units N, G, and A, October 27, 15 hour, A first in hour). In addition, if a data dictionary is used, and entry of the observer's name or initials is not an option in the dictionary, then the observer's name or initials should be included in the file name.

Each user should be familiar with the capabilities of the GPS hardware and field computers. If possible, water quality monitoring staff should receive hands-on instruction from someone familiar with the equipment. At a minimum, the equipment user guides and operator's manuals should be reviewed, and the operator should test the functions s/he intends to use.

It is extremely important that each user become familiar with the battery power and memory capabilities of the GPS units. All units have limited battery and memory resources; these features should be thoroughly tested to gain an understanding of the power and memory limitations of the GPS units before being deployed in the field. It is possible to power or recharge these units from a DC power source, such as a vehicle power outlet.

3.2.3 Data Collection

Data collection should be performed using an approved data dictionary or database for the protocol, if applicable. Moreover, users should be mindful of the following concepts:

- If using a GPS unit that gives an approximate 5m horizontal accuracy, the user cannot map anything as a polygon that is less than 4 to 6m in width or diameter. Such objects must be captured as point features.
- If a GPS user is collecting a line or polygon feature and then stops moving, the GPS unit will continue to collect data (Figure 1, examples 1 and 2). Users need to be familiar with the Pause/Resume toggle key and use it liberally. This technique greatly improves subsequent data quality and reduces the need for time-consuming spatial editing.
- Another way to avoid errors is to collect point features that represent the beginning and end points of a line transect (Figure 1, examples 3 and 4). Having these reference point locations will mean easier editing of any zig-zagging line features.

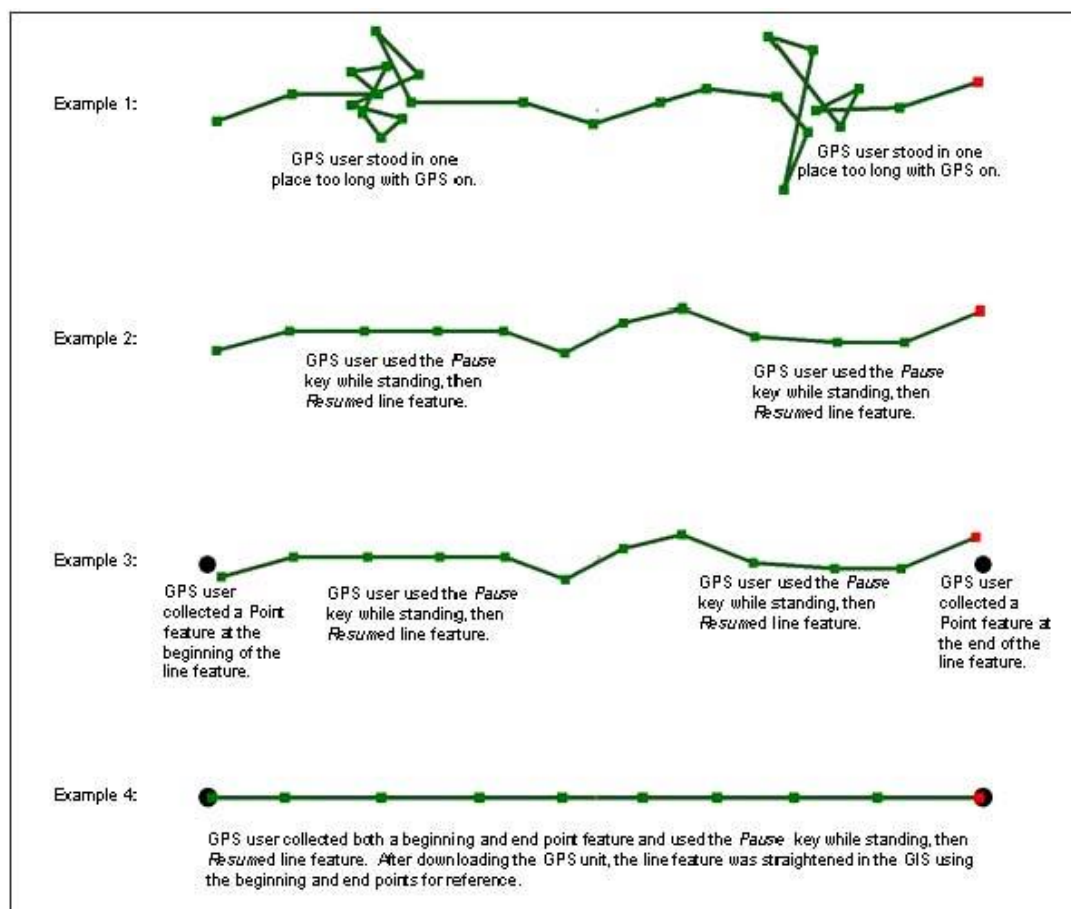


Figure 1. Examples of GPS point and line features data collection.

Mapping-grade GPS units have additional features that aid in data collection. These include:

- *Nested Features*—Allows user to collect a point while collecting a line or polygon feature. For example, while surveying potential amphibian habitat along a stream (line feature), the user can pause the line feature, take a point for a specific observation, then resume the line feature collection.

- *Offset Feature*—Allows user to collect a feature when topography is such that getting next to or over the feature is impossible. For example, a GPS line could be collected while taking a horizontal zooplankton tow off the side of a boat.
- *Between-feature Positions*—the GPS unit collects positions without any feature or attribute data. This feature is useful for tracking areas traveled during a day. For example, while surveying for presence or absence of invasive plants, a user could collect data on the area surveyed in addition to locations of specific plants found.

3.2.4 Data Processing

When data collection is complete for the day or round of sampling, data are downloaded from the GPS unit to a computer. For Trimble GPS units, the proprietary software Pathfinder Office (or the GPS Analyst extension) is used to download, differentially correct, and then export the data to a GIS format. [Note: Trimble Pathfinder Office and GPS Analyst are relatively expensive. However, Trimble also offers a free data transfer utility to download data from the GPS units to a Windows-based PC]. Differential correction is a post-processing procedure to improve upon raw GPS positions using base station data. Base stations consist of a GPS antenna and receiver positioned at a known location specifically to collect data from satellites. The distance between the base station(s) and the remote GPS receiver should be kept to a minimum.

Differential correction should be conducted on all GPS data collected, even if data were collected using the real-time collection feature. Once the data are differentially corrected, they can be verified and edited. Unintentional features can be deleted and attributes can be reviewed.

The last step in processing data is exporting the data set to GIS (ArcGIS or ArcView). Depending on the software used for this process, newly created files generated when exporting data are often assigned generic names. For example, if Pathfinder Office is used to export a file named 'VOYA2007.cor' (.cor denotes that the file has already been differentially corrected) that only contains point features, the exported file will be named 'point_ge.shp'. Great care should be taken to not overwrite this file when exporting other data, as the software will continue to use this generic naming convention the next time it is used. In addition, during the export process, the coordinate system to which the data will be exported to should be verified (Table 2).

Additional data attributes can be included in the data exports. Data attributes recommended by GLKN are listed in Table 3.

Table 3. Recommended fields to be exported in addition to GPS features.

All Features	Point Features	Line Features	Area Features
PDOP	Height	Length (2D)	Area (2D)
Correction status	Position	Length (3D)	Perimeter (2D)
Receiver type			Perimeter (3D)
Date recorded			
Data file name			
Total positions			
Data dictionary name			

Managing the incoming GPS data can be a challenge, especially if there are multiple units per project. Common practices used by GLKN include:

- Download all data to a computer or network drive that is regularly backed up.
- Keep GPS data and GIS data separate through electronic file management.
- Directories and files names should not contain non-alpha-numeric characters and/or spaces (except underscores).
- Keep GPS data in well-organized directories (see Hart and Gafvert (2005), GLKN Data Management Plan, for more details).

At the end of a project, all data and background files should be removed from the GPS unit to free available memory. Data files should not be left on a unit if they have been properly downloaded and verified. In addition, some GPS units require their batteries to be re-charged periodically. Failure to do so can cause the GPS unit batteries to discharge completely and may cause some files and software to be deleted.

Additional information can be found at www.nps.gov/gis/gps/gps4gis/, which describes the steps outlined here in greater detail.

3.3 Using Recreational-Grade GPS Units

Recreational-grade GPS units can be used to acquire location information (generally points) when spatial accuracy is not paramount to the project. Recreational GPS units do not have data dictionaries for storing attribute information with the point location. However, using a recreational-grade unit to capture a waypoint at each sampling site is a reliable means to verify the correct sampling site has been reached, even if a GPS location is not needed.

As with mapping-grade GPS units, personnel that employ recreational-grade GPS units should become familiar with GLKN GPS collection procedures and relevant manufacturer's user guides and operating manuals before GPS operation. For example, prior to using a Garmin 76S (recreational-grade) GPS unit, the following documents should be reviewed:

- Appendix A of this SOP
- GPSMAP 76S Quick Start Guide
- GPSMAP 76S Owner's Manual and Reference Guide
- Garmin MapSource™ User's Manual and Reference Guide

3.3.1 Planning

If a recreational-grade GPS meets the criteria of the project, the unit chosen must have the capability of downloading collected data to a personal computer. Downloading data is usually accomplished with a parallel or USB cable connection.

Much of the data collected by GPS will eventually reside in a relational database. Each GPS feature collected should contain a unique identifier that relates the feature to an associated record in a database. For water quality monitoring on inland lakes, the records associated with each GPS feature will consist primarily of water quality parameters. Since recreational GPS units have only one text field for input, careful consideration should be given to the use of this field and the design of unique identifiers. GLKN data management and GIS staff can assist in creating unique IDs on a project-by-project basis.

3.3.2 Data Collection

Location data are captured by recreational-grade GPS units as *waypoints*. When taking a waypoint, enter the site ID or site designation in the text field provided. It is also good practice to collect reference points at regular intervals. These reference point positions should be taken at known locations (e.g., trailheads, parking lots, stream confluences) which can later be used in GIS to check the accuracy of waypoint data.

If navigation to preset waypoints is applicable to a project, the waypoints must be loaded onto the GPS unit before departure to the field. Some recreational grade GPS units have the ability to store and display topographic maps, which can aid in navigation. Printed topographic maps of the waypoint locations can also be used to maximize field time and efficiently navigate between waypoints.

3.3.3 Data Processing

Data should be downloaded from GPS units once a day or after each field session. The DNR Garmin freeware product (www.dnr.state.mn.us/mis/gis/tools/arcview/index.html) can be used to download data from Garmin GPS units. Data should be downloaded both as a text file and a shapefile. Each file name should include the download date. Points should be checked for reasonable spatial accuracy and errors. Subsequent downloads should be error-checked in the same manner. When data collection is finished, all files should be compiled into one spatial file, and along with the raw downloads, should be saved to the appropriate location on Great Lakes Network servers (refer to SOP #8, Data Entry and Management for more detail).

3.4 Metadata

Regardless of the type of GPS unit used to collect data, all resulting GIS datasets need to have information documenting how the GPS data were collected. NPS requires that FGDC (Federal Geographic Data Committee, www.fgdc.gov/index.html) compliant metadata be written for all geospatial layers created (Executive Order 12906).

Until final FGDC metadata is written, the data collection and management process is incomplete. Tracking GPS projects depends on the complexity of the project, how many participants, length of project etc. Documentation can be a simple ‘readme’ text file, or a detailed daily log.

The Great Lakes Network recommends formal metadata be written by the data collectors, as they are the ones familiar with the project and resulting data. However, network data management and GIS staff usually end up documenting someone else’s work. Chapter 7 of the GLKN Data Management Plan (Hart and Gafvert 2005) includes a detailed discussion of metadata procedures. At a minimum, the following details should be documented to facilitate final FGDC metadata:

- Name of project
- Name(s) of data collectors
- EHE/EPE or maximum PDOP (using 4 satellites)
- Coordinate system (projection, datum, and zone)
- Type (or types) of GPS units used
- The range of field collection dates
- Name of base station(s) used for differential correction
- Name and version of software used for downloading
- Any major editing performed on the raw data (e.g., moving of points)
- All versions of data dictionaries used

3.5 GPS and NPSTORET

Water quality data, including chemical, physical, and biological data, are managed according to guidelines from the NPS Water Resources Division. These guidelines include using the NPSTORET desktop database application to help manage data entry, documentation, and transfer. The network oversees the use of NPSTORET according to the network’s water quality monitoring protocols and ensures the content is transferred at least annually to NPS Water Resource Division for upload to the EPA STORET (STORage and RETrieval) database.

NPSTORET requires that every water quality monitoring station location must have an assigned latitude and longitude coordinate. Also, the horizontal datum to which these coordinates are referenced (typically North American Datum 1983 or World Geodetic System 1984) and the method by which they were obtained (GPS, map interpolation, etc.) must be provided. Therefore, the GLKN project leader for monitoring water quality on inland lakes and the GLKN data manager collaborate in organizing monitoring station coordinates in an acceptable format (e.g., Excel spreadsheet or Access database) to be imported to the NPSTORET database. A detailed discussion on using the NPSTORET database is found in SOP #8, Data Entry and Management.

3.6 QA/QC

Long-term monitoring is only useful if stakeholders have confidence in the data. Efforts to detect trends and patterns in ecosystem processes require high-quality, well-documented data that minimize error and bias. Data of inconsistent or poor quality can result in loss of sensitivity and lead to incorrect interpretations and conclusions.

NPS Director's Order #11B: Ensuring Quality of Information Disseminated by the National Park Service (www.nps.gov/policy/DOrders/11B-final.htm) specifies that information produced by the NPS must be of the highest quality and based on reliable data sources that are accurate, timely, and representative of the most current information available. Therefore, GLKN will establish and document procedures for quality assurance (QA) and quality control (QC) to identify and reduce the frequency and significance of errors at all stages in the data life cycle (see SOPs #8 and #12 for details on data management and QA/QC, respectively). Under these procedures, the progression from raw data to verified data to validated data implies increasing confidence in the quality of those data. Quality assurance and quality control procedures will document internal and external review processes and include guidance for addressing problems with data quality.

Examples of general of QA/QC practices include:

- Standardized field data collection forms
- Use of field computers and automated data loggers
- Proper calibration and maintenance of equipment
- Training of field crew and data technicians
- Database features such as built-in pick lists and range limits to reduce data entry errors
- Automated error-checking routines

Many of the standard operating procedures associated with the protocol for monitoring water quality in inland lakes include a discussion of QA/QC as it relates to the protocol. Examples of QA/QC practices pertaining to use of GPS include:

- Ensure that GPS-related software is periodically updated as it becomes available and has been tested.
- Record location positions on field data forms as well as with the GPS unit.
- For each monitoring station, compare location positions for different sampling events, including the position recorded during establishment of the monitoring station. This will allow for an assessment of position accuracy over time.
- If data dictionaries are used with mapping-grade GPS units, ensure that the coordinates for the monitoring station match the other attributes recorded on the GPS unit for that monitoring station.
- Check to see if the accuracy of the GPS unit meets or exceeds the National Map Accuracy Standards shown in Table 1 of Appendix A.
- Ensure that the appropriate coordinate system is used when collecting and exporting data.
- Use mapping software (e.g., Pathfinder Office or ArcGIS 9.x) to view waypoints (or features) overlaid on a geo-referenced air photo or topographical map to check for accuracy.
- If applicable, check the accuracy of the attribute(s) recorded on a GPS unit by using mapping software (see bullet above) and look-up tables or in spreadsheets generated after post-processing is complete.

A final report on data quality, including data collected by GPS, will be incorporated into the documentation for this project. Such documentation will include a listing of the specific methods used to assess data quality and an assessment of overall data quality prepared by the project manager. This is a necessary part of the data quality elements of the metadata file.

3.7 Literature Cited

- Hart, M., and U. Gafvert (editors). 2005. Data management plan: Great Lakes Inventory and Monitoring Network. National Park Service Great Lakes Inventory and Monitoring Network Report GLKN/2005/20. National Park Service, Ashland, Wisconsin.
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Appendix A

This appendix discusses the role of GPS in GLKN data management and provides an explanation of the types of GPS units that are available. The text is taken directly from the GLKN GPS Field Collection Guide, which can be found in its entirety in Appendix K of the Great Lakes Inventory and Monitoring Data Management Plan (Hart and Gafvert 2005).

Introduction

Over the past decade new tools have been developed to help researchers collect and manipulate data while in the field. Global Positioning System (GPS) is one such tool. GPS is currently a constellation of 28 US Department of Defense satellites (as of 2006) orbiting 11,000 miles above the Earth, making a complete orbit approximately every 12 hours, and transmitting signals to Earth at precisely the same time. The position and time information transmitted by these satellites is used by a GPS receiver to triangulate a location coordinate on the earth using three or more satellites.

Role of GPS in GLKN Data Management

Data collected using GPS-enabled equipment represents all or part of the acquisition stage of an information resources lifecycle that includes several other stages (see Section 5.4 in GLKN Data Management Plan). The process and methodology used for acquisition, planning, data collecting, and post-processing incorporate several aspects of data management, including quality assurance, data storage and organization, and data stewardship. To promote data quality and simplify data management, the Great Lakes Network expects to use electronic data logging equipment for some data acquisition. However, parallel or complementary use of hand written data sheets and field notes will remain important for data collection activities.

Types of GPS Units

At the most basic level GPS equipment can just consist of a GPS antenna and the associated signal processing circuitry. The antenna can be a standalone device, be incorporated in to a handheld unit, or be integrated into a larger electronic device, such as a personal data assistant (PDA), data logger, or portable computer. As technology evolves, the Great Lakes Network will continually try to use equipment which maximizes spatial accuracy; reduces hardware weight and user fatigue; and reduces database development, data manipulation, and transformation.

There are three major types of GPS units that are based on the level of accuracy to which spatial data can be collected. Survey-grade GPS units are used for surveying tasks that require very high accuracy (1 cm or less). Mapping-grade units can map features from sub-meter to less than 5m accuracy, employing differential correction. Recreational-grade GPS units are sold primarily for outdoor sports and recreational activities. Accuracy using recreational GPS units ranges from 5 to 30m. Most natural resource-related data collection requirements correspond to either the recreational-grade or mapping-grade. Figure 1 shows some of the major differences between these two types.

Deciding which type of unit to use is an essential part of project planning, and depends on the end product needed. Mapping-grade GPS units are recommended for most GLKN field work; however, for some projects recreational-grade units can meet a project's accuracy requirements and reduce the

cost of field operations. The choice of GPS unit should be made by the project manager after consulting with the GLKN data management and GIS staff.

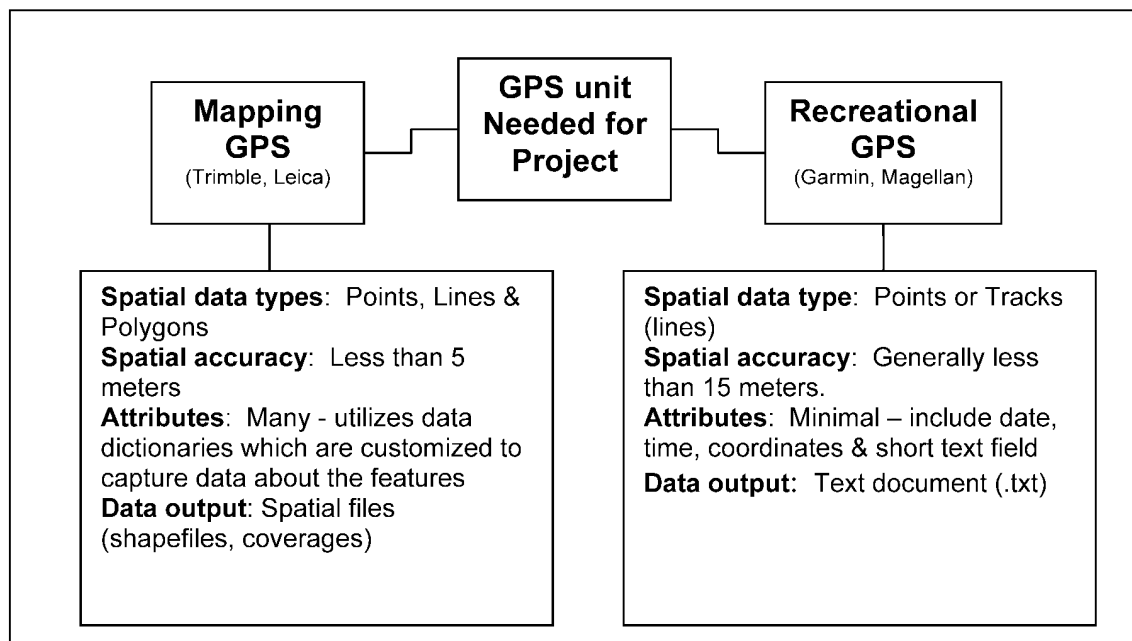


Figure A1. Differences between different grades of GPS units.

All resulting GIS data layers need to meet or exceed the National Map Accuracy Standards for a 1:24,000 product (NPS GIS Data Standards, 2002, www.nps.gov/gis/data_info/standards.html). Table A1 provides the allowable horizontal accuracy for some common scales.

Table A1. Map scales and allowable error.

Scale	Allowable Error
1:40,000	33.8 meters (111 feet)
1:31,680	16.1 meters (53 feet)
1:24,000	12.2 meters (40 feet)
1:20,000	10.1 meters (33 feet)
1:12,000	6.1 meters (20 feet)
1:9,600	4.9 meters (16 feet)
1:4,800	2.4 meters (8 feet)
1:2,400	1.2 meters (4 feet)
1:1,200	0.6 meters (2 feet)

Definitions

Accuracy: The degree of conformance between the estimated or measured position, time, and/or velocity of a GPS receiver and its true time, position, and/or velocity as compared with a constant standard.

Almanac: Data transmitted by a GPS satellite, which include orbit information on all the satellites, clock correction, and atmospheric delay parameters. The almanac is used to facilitate rapid satellite vehicle (SV) acquisition. The orbit information is a subset of the ephemeris data with reduced precision.

Attribute: Tabular information about a specific feature.

Base Station: GPS files collected continuously from community base stations, local base stations, or Continually Operating Reference Stations (CORS). Gathering base files will require an internet connection and software that dials into a server that houses the base station data collected at the same time of the rover. Data stored on these servers will not be available in real-time - hence this step is conducted after field collection. Trimble users would use the Differential Correction utility supplied in Pathfinder Office.

Differential Correction: The merging of rover file data with base map data to correct position errors due to atmospheric interference. Autonomous data (rover) are collected in the field while base data are stored at the stationary base station. The two datasets are loaded into a post-processing software package where corrections are applied. This process will reduce errors in the field collected data (the rover) by correlating and correcting for known errors recorded in the base file that has the same time tag. As distance between the rover and base file increase, there is degradation in post-processed accuracy. In general, a degradation of one part per million (1ppm) occurs as the distance between the base station and rover increases. For example, one millimeter of degradation occurs for every kilometer between base and rover.

Datum (*geodetic datum*): A mathematical model that is designed to fit a point on the earth's surface to an ellipsoid. Commonly used datums are North American Datum (NAD) 1927, and NAD 1983, modeled to represent the North American continent.

Feature: A feature is the spatial location of a physical object, or some event or phenomenon. Features are often referred to as graphic data in a GIS. Examples include a tree (point), road (line), or land parcel (polygon).

FGDC: The Federal Geographic Data Committee is a 19 member interagency committee composed of representatives from the Executive Office of the President, Cabinet-level and independent agencies who develop policies, standards, and procedures for organizations to cooperatively produce and share geographic data. (www.fgdc.gov/index.html).

Global Positioning Systems (GPS): A constellation of a minimum of twenty-four satellite vehicles orbiting the earth approximately every twelve hours at an approximate pacing of sixty degrees, between 11,000 – 12,000 miles above the surface of the Earth

Lines: Geographic term related to the scale that describe how a feature is drawn. Lines are linear measures of a feature (such as a line representing a trail)

Mapping Grade: GPS receivers capable of attaining five meters of accuracy or better using differential correction.

Metadata: Data about the data. Usually comes in the form of a text or html document with information on the dataset's quality, current projection, attributes, distribution and citation. In the National Park Service, this generally implies a file compliant to the FGDC Content Standard for Digital Geospatial Metadata.

Multipath: Error which occurs when a GPS signal sent from a satellite vehicle is bounced or redirected by an object, prior to reaching a GPS receiver. Multipath will cause the time it takes a GPS signal sent by a satellite vehicle to reach a GPS receiver to be inflated. This will cause inaccuracies in positions collected.

Points: Geographic term related to the scale that describe how a feature is drawn. Points are single dimensional features (such as a point representing a spring).

Polygons: Geographic term related to the scale that describe how a feature is drawn. Polygons have area associated with the feature (such as a circle representing a parking lot).

Projection: A method of representing the earth's three-dimensional surface as a flat two-dimensional surface. This normally involves a mathematical model that transforms the locations of features on the earth's surface to locations on a two-dimensional surface.

Post Processing: Utilizing base station data, GPS software, and data acquired by a GPS receiver in the field to gain an accurate fixed position.

Triangulation: The process of determining the distance between points on the earth's surface by dividing up a large area into a series of connected triangles, measuring a base line between two points, and then locating a third point by computing both the size of the angles made by lines from this point to each end of the base line and the lengths of these lines.

Waypoint: A named three-dimensional position on the earth's surface, that is, having both a latitude and longitude. Waypoints are assigned to a fixed location in the field so it can be navigated to consistently and accurately through time.